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Assessment of Stressors on Fall-Run Chinook Salmon in Secret Ravine (Placer County, CA)

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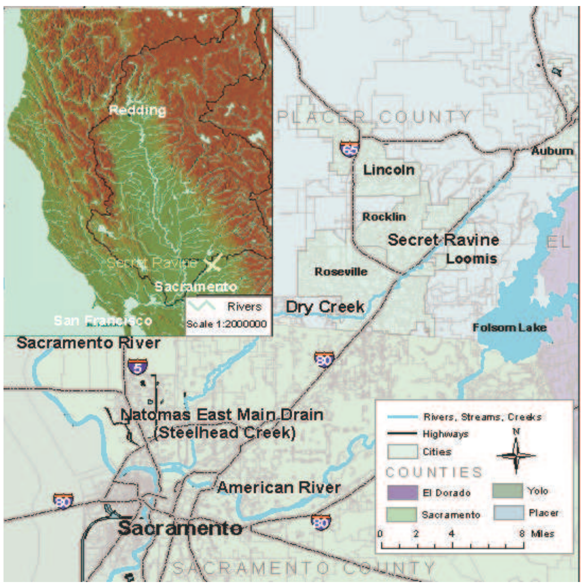


LOCATION OF SECRET RAVINE WITHIN THE SACRAMENTO RIVER WATERSHED

Introduction

Secret Ravine is a 10.5 mile-long creek located east of Interstate-80 in Placer County. The stream is part of the upper Central Valley watershed, and is a tributary of Dry Creek, which drains into the Sacramento River.

Secret Ravine supports a population of fall-run chinook salmon, but has experienced an estimated ten-fold decline in the last forty years, a rate even higher than the similar declining trend of chinook salmon in the Central Valley over this same time period.[i] "The chinook salmon is the preeminent anadromous[2] fish in California, whether measured by economic value, popular recognition or ecological importance".[ii] The Central Valley fall-run species has maintained populations high enough to prevent them from being listed as Endangered under the Federal Threatened and Endangered Species List in California. However, their designation as a Candidate Species for "Threatened" status, without actual federal protection, makes assessment and mitigation of their decline even more urgent. Proliferation of salmon in smaller tributaries such as Secret Ravine is also thought to contribute highly to preservation of genetic diversity in larger rivers such as the American and Sacramento.[iii]

A STRETCH OF SECRET RAVINE

Causes for this decline can generally be attributed to urban encroachment, pollution and other forms of land use alteration. Secret Ravine stakeholders were interested in targeting the causes of decline within the Secret Ravine watershed because it is considered to have the best spawning habitat in the immediate area.[iv] Under the guidance of CalEPA, group members were charged with developing an ecological risk assessment (ERA) to compare the various threats of anthropogenic stressors on fall-run chinook salmon. Based on the results, we prioritized sources and stressors for local organizations so restorative and preventative measures could be taken to protect the salmon population.

[1] Faculty Advisors: Bruce Kendall, Ph.D and Carol McAusland, Ph.D
[2] **anad·ro·mous:** ascending rivers from the sea for breeding. http://www.webster.com/cgi-bin/dictionary.

Significance and Scope

The scope of our study concentrates on stressors located in Secret Ravine proper. Our analysis eschews stressors related to adverse affects in the ocean, in the delta and in the larger tributaries, even though fall-run chinook spend a significant portion of their life cycle in these areas. However, as parts of each life stage occur in Secret Ravine, we had cause to focus our efforts in the creek.

Roseville, the city into which Secret Ravine drains, is also the fastest growing in Northern California. The cities surrounding the watershed have undergone complex transformation: from placer and hydraulic mining, to orchard use, to suburban and residential development.

The Secret Ravine watershed contains a canal system still in place from the Mining Era, which contributes to an altered flow regime. The creek is characterized by patchy substrate of high quality gravel overlain by excess fine sediment, or sand, and fairly adequate temperatures for all life stages of fall-run chinook. The creek also contains high-quality macroinvertebrate food supply for juveniles, fair - but highly invaded - riparian cover, and a relatively high density of beaver dams. Dry Creek (downstream of Secret Ravine) had been assessed 100% toxicity levels in previous habitat surveys, so there was also cause for concern for high toxicity levels in Secret Ravine.[v]

An ecological risk assessment "is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors".[vi] Within the ERA framework, we used available data and information to help understand and predict the links between sources, stressors and their resulting ecological effects.

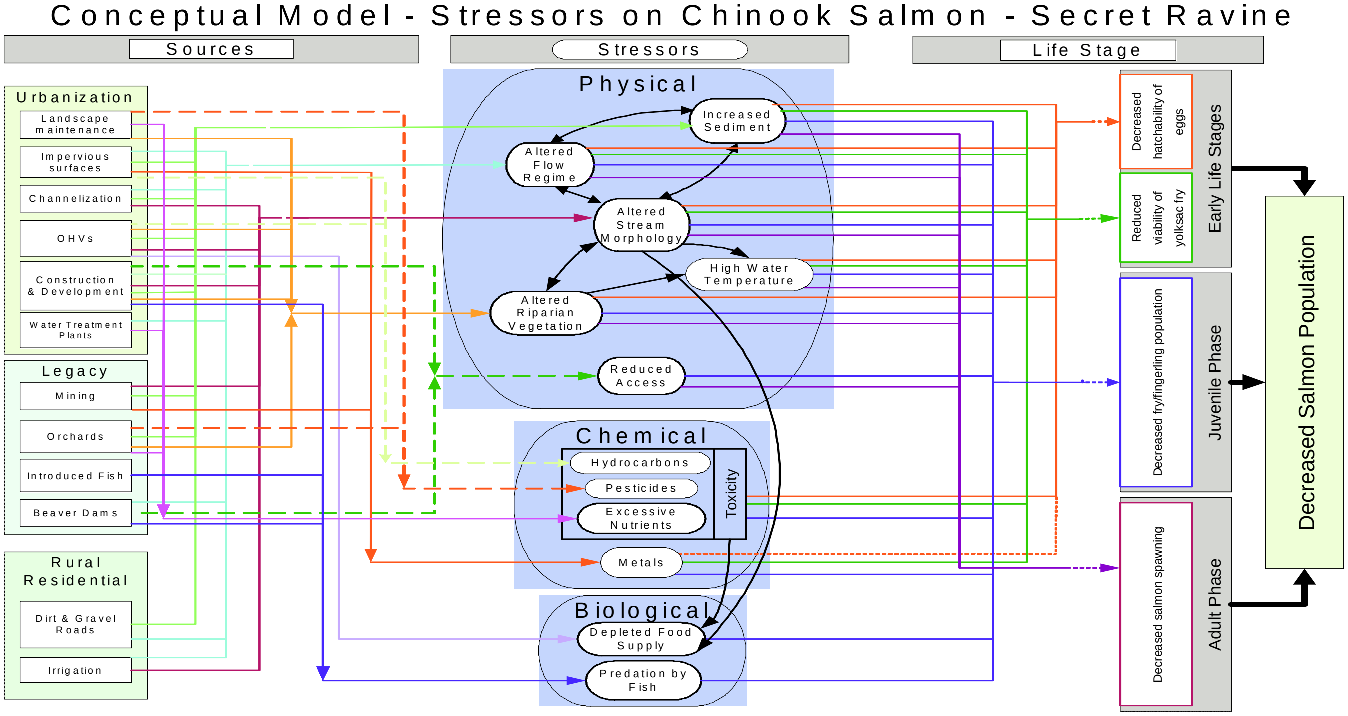
There are three phases of an ERA: 1) problem formulation; 2) risk analysis; and 3) risk characterization.[vii]

Problem Formulation

Problem formulation, the first phase of an ERA, includes a clear definition of the problem, and a plan for analyzing and characterizing risks. In consultation with our stakeholders we chose reproductive success of the fall-run chinook to be our assessment endpoint. Our endpoint, based on the viability of each life stage, depends upon completion of the life-cycle (e.g. the ability of an adult to reach spawning grounds and reproduce; the ability of the eggs to hatch; or the ability of the alevin to emerge from the redds, etc.).

The conceptual model we designed delineates the pathways that connect all possible sources (twelve on our system) to all possible stressors (ten on our system) to the three major life stages of the salmon that occur in Secret Ravine.

Conceptual Model - Stressors on Chinook Salmon - Secret Ravine



Risk Analysis

Risk analysis evaluates the ecological impact that will occur from exposure to a stressor and determines the method for evaluating risk posed to the endpoint of the ERA.

Two models were used to characterize risk in Secret Ravine: the Modified Relative Risk Model (MRRM) and the Stressor-Driven Risk Model (SDRM). The Relative Risk Model (RRM) is a specialized form of ecological risk assessment developed by Dr. Wayne Landis of Western Washington University. Initially, this model gave us a systematic way to quantify ecological risk posed by sources and stressors in Secret Ravine. Using the Relative Risk Model (Landis 1997) as a template, we developed a Modified Relative Risk Model specific to Secret Ravine.

The Modified Relative Risk Model (MRRM) combines quantitative source analysis of land use through Geographic Information Systems (GIS) and reference values to estimate biological, chemical and physical stressors to the salmon. Based on these estimates, data for the region are converted into a ranking system. A risk score, or the quantification of risk, is calculated for sub-watersheds (or "risk regions"), sources, stressors, and habitats.

In order to address the limitations of the traditional RRM and the MRRM, we developed the Stressor-Driven Risk Model. The crux of the Stressor-Driven Risk Model lies within the use of percent effect (percent habitat reduction or percent reduction in population) specific to the three life stages of salmon. These percentages are calculated using dose-response curves, reference values or habitat loss estimations. Quantification of risk for sources and stressors is expressed as 'percent effect,' rather than as ranks. This eliminates problems associated with multiplying ranks throughout the model, and gives the SDRM greater biological precision.

The MRRM uses analysis of sources, stressors, habitats[3] and exposure filters[4] to qualify risk. The SDRM uses predominantly stressor effects to determine risk. Both use a combination of data from the creek and literature to estimate these relationships.

At its best, the data included one to three years of sampling sites collected on Secret Ravine throughout the extent of the watershed (sediment, morphology, toxicity, metals and food supply) and strong support of these data in the literature and from local experts. At worst (as in the case of flow), there was very little actual associated data, the stressor analysis only had enough extrapolated data to focus on one criterion associated with that stressor (e.g. scour), and there was high natural variability associated with the stressor itself. All data suffered from limited sampling sites over limited years.

Risk Characterization

Risk characterization describes the actual assignment of values to each of the risk factors and includes a summary of assumptions, scientific uncertainties, strengths and limitations of the analysis.[viii] The Modified Relative Risk Model uses ranks to characterize effects in each risk region, while the Stressor-Driven Risk Model integrates the "percent effects" of each of the stressors across the entire watershed.

An equation that incorporates ranks with habitat, exposure and effect was used to calculate a risk score for the MRRM.

Risk Score = (Source Rank) x (Habitat Rank) x (Effects Rank)x (Exposure 1 filter) x (Exposure 2 filter)

The SDRM quantifies stress in terms of effect on fish populations. To better discern the impact of stressors, the effect was translated into percent mortality or percent reduction in habitat for each life stage. Once the percent effect of an individual stressor is determined, the percent effect for each life stage was multiplied together. In essence, the product simulates the percent survival of fall-run chinook salmon through the three life stages in Secret Ravine. The percent effect result is subtracted from one and multiplied through the three life stages. This value is subtracted again from one, rendering a total percent effect.

$$\textbf{Total Percent Effect}_{\text{(per stressor)}} = 1 - [(1 - PE_{egg}) \times (1 - PE_{juvenile}) \times (1 - PE_{adult})]$$

In the uncertainty phase of risk characterization for the MRRM, we measured the sensitivity of the assignment of the ranks to the total risk scores. With the SDRM, we estimated the uncertainty of our results based on the natural variability of the system.

[3] "Habitat" is used as another parameter to capture the affected life stages of salmon (as opposed to conventional ecosystem-type habitats used in a regional risk assessment). Habitat in our study refers to the water column, the benthos, or both.

[4] The first exposure filter (Exposure 1) assesses whether or not the source emits the stressor. The second exposure filter (Exposure 2) assesses whether or not the habitat will be exposed to the stressor.

Results and Recommendations

Sediment, flow and morphology ranked as the top three stressors in the MRRM, while sediment, reduced access and toxicity ranked as the top three stressors in the SDRM.

Top Three Stressors

Modified Relative Risk Model	Stressor Driven Risk Model
Sediment	Sediment
Flow	Reduced Access
Morphology	Toxicity

Despite large differences in the risk characterization phases of these models, sediment ranked highly in both models. This in part demonstrates the impact of the conceptual model in elucidating ecosystem pathways on Secret Ravine. Because sediment ranked highly in both models, we have confidence that this stressor may be particularly problematic for Secret Ravine. Although flow and morphology did not register as the highest stressors in the SDRM, these stressors are associated with the "sediment-flow-morphology" cycle on the conceptual model and should be addressed in any management plan. Reduced access and toxicity stand out as two glaring omissions from the MRRM. Reduced access, the lowest-ranking stressor in the MRRM, had few sources, while toxicity, with the third lowest risk score, had only one habitat (the benthos) associated with it. However, reduced access is the only stressor that deals directly with the potential consequences of delay in adult spawning and in juvenile emigration. Thus, it is reasonable to conclude that reduced access would pose a high risk to salmon and may be a high-ranking stressor. Toxicity can cause high mortality during the early life stages of fall-run chinook, especially in regards to heavy metals that may be associated with mine tailings. Thus it was reasonable to expect that this stressor would pose some of the worst risk to the fish.

Consequently, sources associated with stressors registering the highest percent effects - that also had the highest magnitudes - were discussed. Sediment had eleven total contributing sources. Impervious surfaces and off-highway vehicles were the leading sources causing increased sediment in Secret Ravine. Both non-structural and structural management practices should be implemented to prevent sediment loading. Of the five sources contributing to toxicity, impervious surfaces, landscape maintenance and waste treatment plants are the highest potential contributors. In areas where impervious surfaces are extensive, we recommend that localized bio-filtration devices should be installed to minimize the effects of peak flow runoff. While the benefits of beaver dams seem to be outweighed by the physiological costs to the fish of reduced access itself, the monitoring and breaching of particularly problematic beaver dams needs to be considered in more detail.

This study gave us the opportunity to experiment with the suitability of performing an ecological risk assessment for chinook salmon. While the MRRM may be best used for determining the most important stressors (risk) to a system in a preliminary fashion (and as a data-needs assessment tool) the Stressor-Driven Risk Model demonstrates that ecological risk assessments can also convey biologically meaningful results in absence of a complete data set. Indeed, the SDRM had the ability to estimate that stress internal to Secret Ravine was responsible for half of the mortality associated with the entire life cycle of the fish migrating through this watershed. Thus, we strongly feel that ecological risk assessments that are biologically-sensitive to the needs of the species are an important first step in resolving problems associated with declining salmon populations. Although both models suffer from an inability to accurately account for the contributions particular sources make to stressors on the system, we are confident in the magnitudes we assigned to sources in the SDRM. We could thus use these magnitudes to estimate the impact that mitigating them would have on improving salmon health. The models highlight sources of concern. Any future analysis of source contributions necessitates a separate study in itself.

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[i] Gerstung, E.R. 1965 May 25. Memorandum Re: 1964 Fall-run king salmon inventory on tributaries of the Natomas East Drain and Natomas Cross Canal. By the State of California, The Resources Agency To Wm. O. White, Fisheries Manager II.; Dry Creek Conservancy. 2001. Secret Ravine Adaptive Management Plan. Roseville, CA.

[ii] Yoshiyama, R.M., F.W. Fisher, P.B. Moyle. 1998. "Historical abundance and decline of chinook salmon in the Central Valley region of California." *North American Journal of Fisheries Management* 18: 487-521.

[iii] Dry Creek Conservancy. 2001. Secret Ravine Adaptive Management Plan. Roseville, CA.

[iv] Bates, G. President, Dry Creek Conservancy. Personal communication with FISH Group, 2002-2003.

[v] Supra. Bates, G.

[vi] U.S. Environmental Protection Agency. 1998. Guidelines for Ecological Risk Assessment. Washington, D.C. Risk Assessment Forum. EPA/630/R-95/002F.

[vii] Supra. U.S. Environmental Protection Agency.

[viii] Supra. U.S. Environmental Protection Agency.